Building-integrated photovoltaics in Norway

A case study of Brynseng elementary School

Helmine Osmundsen

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Author

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Author: Helmine Osmundsen

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Summary

Climate change is on the agenda around the world, and it is important that it is taken seriously. The building sector is responsible for a large amount of the greenhouse gases released into the atmosphere. This issue, including the fact that more and more people are moving to cities, it is necessary to look towards new solutions that can benefit society in more ways than one.

Solar energy is becoming more and more prominent, and long with this energy solution, building-integrated (BIPV) has emerged as a possible to solution. BIPV includes building materials and solar panels, and it is a technology that can provide energy and provide the same uses as building materials do. BIPV has not become competitive on the market yet, and that is what I will study in my thesis. These are the research questions I will study:

1) How can BIPV become a competitive product on the market in Norway?
2) How can the case of the Brynseng school help the future of BIPV in Norway?

The Brynseng school is one of the first schools with a BIPV facade, and it is therefore an interesting topic to study.

I will apply the technological innovation systems (TIS) framework for my thesis.

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Abbreviations

BAPV: Building-attached photovoltaics

BIPV: Building-integrated photovoltaics

EEA: European Economic Area

IPCC: The Intergovernmental Panel on Climate Change

NSD: Norwegian Centre for Research Data

NSI: National Systems of Innovation

nZEB: near-zero emission building

OWP: Off shore wind power industry

REC: Renewable Energy Corporations

TIS: Technological Innovation Systems

PV: Photovoltaics.

UN: United Nations

UNFCCC: United Nations Framework Convention on Climate Change

ZEB: Zero emission building

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Chapter 1: Introduction

The global issue of climate change

The United Nations (UN) defines climate change as one of the most defining issues of our time and emphasises that the world has to take action now to be able to do something about it (*un.org*). The last four years have been the four hottest years on record and the temperature in the Arctic has risen by 3 degrees Celsius since 1990 (*un.org*). Climate change has and will have more effects on health due to pollution in the air, more heatwaves, and the world´s food security being at risk (*un.org*). Throughout the years, the world has several times tried to come together to reach a consensus on climate change goals, the most recent one being the Paris Agreement. The Paris Agreement is an agreement under the United Nations Framework Convention on Climate Change (UNFCCC) and was adopted on the 12th of December 2015 and 195 members of the UNFCCC have signed the agreement and 186 have become party to the agreement (*treaties.un.org*). This means that most countries in the world have taken upon themselves to try and secure a better future and wellbeing for the next generations, which is a big accomplishment. It is also important to emphasise that the fact that so many countries have reached a consensus to reduce the amount of emissions released into the atmosphere, because it is not often that a multilateral agreement of this importance and calibre is ratified.

Climate change has been on the radar for many years prior to the Paris Agreement. The Intergovernmental Panel on Climate Change (IPCC) has made an overview over the history of climate change, where one has studied the climate and the changing aspect of climate for many years back.

Renewable energy solutions

In order to combat climate change and make a change in the world, there needs to be innovative solutions that are sustainable and affordable. The industrialised nations in particular have to make them less dependent on the oil and gas sector, which will reduce the greenhouse emissions and contribute to reaching the goals set in the Paris Agreement. There needs to be a transition from dependence on oil and gas, and other industries that contribute to the polluted atmosphere.

It is almost peculiar how we today are so intertwined with these sectors, especially since many years before the oil was discovered, renewable energy was the main, and often only, source of

energy available (Sørensen, 1991, p. 8). Energy from the sun, solar energy, was the main source of energy used for heat and grow food (Sørensen, 1991, p. 8). Historically, renewable energy was the only tool available to make things go around. Wind energy for sail ships, there is evidence of windmill use in India for about 2500 years ago, and the Greek civilisations used solar energy in minor ways (Sørensen, 1991, p. 8). The European Renaissance brought about a new interest in technology, and the centuries that followed, many experimented with different energy solutions (Sørensen, 1991, p. 8). As years go by, civilisations are starting to take shape, and with this change, humans´ energy use increased (Sørensen, 1991, p. 8).

Solar photovoltaics (PV).

Since the 1970s and 1980s, there has been research activities related to the development of raw-materials for solar PV in Norway (Normann and Hanson, 2015, p. 12). The first firm that manufactured PV in Norway, was the firm Scanwafer, which emerged on the scene in the mid-90s (Normann and Hanson, 2015, p. 12). In the years that followed, other firms grew, and the Renewable Energy Corporation (REC) became the large player on the global scale in the 2000s (Normann and Hanson, 2015, p. 12). During this time, the entry of firms were usually determined by growth expectations in markets overseas and it mostly consisted of material and component suppliers (Normann and Hanson, 2015, p. 12). There were increased development of new ways of producing silicon for PV use, similar to those created by Elkem Solar (Normann and Hanson, 2015, p. 12).

Later on, China emerged on the PV scene, which led to a massive increase in production and the price decreased (Normann and Hanson, 2015, p. 12). As a result, many firms closed down, REC in Norway being one of them (Normann and Hanson, 2015, p. 12). However, other firms, such as Scatec Solar, have later emerged as global players in the PV industry (Normann and Hanson, 2015, p. 12).

In Norway, the deployment of PV has for the most part been below 500 kWp (kilowatt peak) installed annually, where most of these installations were on either lighthouses or holiday cabins through off grid solutions (Normann and Hanson, 2015, p. 12). However, recent years suggests increase in investment in PV technologies (Normann and Hanson, 2015, p. 12).

Uncertain demand might also be a challenge for firms, and both of these challenges are linked to the market access and weak domestic markets for PV (Normann and Hanson, 2015, p. 29).

Product costs and service development is also a challenge, which could point towards a need for better financing (Normann and Hanson, 2015, p. 29).

The building sector and climate change

The building and construction sector accounts for 36% of the global final energy use and 39% of CO2 emissions released into the atmosphere (UN Environment, 2017, p. 6). This makes the building and construction sector an important sector to improve and transition into a more sustainable sector. The building sector is also expected to continue to grow along with urbanisation processes. 99.5% of the direct energy use the global construction sector are from fossil fuel (Huang et.al., 2018, p. 1914). Usually this is due to on-site construction operation with the use of machinery and other equipment (Huang et.al., 2018, p. 1914). The emission released into the atmosphere increases with idling non-road diesel construction equipment (Huang et.al. 2018, p. 1914). By improving the efficiency of the building and construction sector, it could reduce the carbon emissions quite a lot (Huang et.al., 2018, p. 1914).

Since the Paris Agreement, the goal for the world to reach below 2 degrees Celsius, is already a part of many countries' strategies, but the building sector might not have had the same momentum (UN Environment, 2017, p. 8). However, the demand for renewable energy solutions as well as high energy efficiency, the focus on zero emission buildings (ZEB) have become more prominent (Jelle and Breivik, 2012, p. 68). Certifications for environmental friendly buildings have been introduced for many years, starting the BREEAM certification, which was introduced in 1990 (The Norwegian Green Building Council, *byggalliansen.no*). It is a leading certificate in Europe, and BREEAM-NOR is the Norwegian customization (The Norwegian Green Building Council, *byggalliansen.no*). The aim is to promote sustainability in the building sector, and the certificates can be issued in five levels: pass, good, very good, excellent, and outstanding (The Norwegian Green Building Council, *byggalliansen.no*). All of these reasons are important going forward for the building sector, but what are the ways to accomplish this?

Buildings need to be able to have energy available and the sun is an obvious source of energy for that to be accomplished (Jelle and Breivik, 2012, p. 68). Buildings with building-integrated photovoltaics (BIPV) can therefore be a useful tool for in order to meet these demands, because it embodies various tasks, such as producing electricity (Jelle and Breivik, 2012, p. 68). They

are also usually integrated into the architecture and part of the building´s design (Jelle and Breivik, 2012, p. 69).

Building-integrated photovoltaics (BIPV)

BIPV is an innovation that can be integrated into the facade of buildings and function as construction materials (Lu et.al., 2018, p. 400). The function of BIPV can be many, such as heat insulation, structure, weather protection, noise protection, and they can provide nice aesthetics for the building (Lu et.al., 2018, p. 400). Building integration of PV cells can be done on roofs (sloped and flat), facades, and on solar shading systems (Jelle and Breivik, 2012, p. 69). PV cells can be mounted on existing roofs or facades, whilst BIPV systems replaces part of the building material and therefore have various benefits to it (Jelle and Breivik, 2012, p. 69).

There is a range of BIPV products available that can be categorized into four groups based on the descriptions of the product from the manufacturers: BIPV foil products, BIPV tile products, BIPV module products, and solar cell glazing products (Jelle and Breivik, 2012, p. 71). Foil products involves flexible systems and it is suitable for flat roofs that cannot take too much heavy weight (FME Susoltech, 2018, p. 7) and it also is very easy to install (Jelle and Breivik, 2012, p. 71). The PV cells are usually made from thin-film cells, which is to preserve the flexibility and efficiency with regards to high temperatures when using it on roofs with no ventilation solutions (Jelle and Breivik, 2012, p. 71). The downside with this product is that there are few weather tights solutions, the fill factor is quite low which is due to low efficiency and solar cell resistances to thin-film cells (Breivik and Jelle, 2012, p. 71). Solar glazing products are modules for solar shading and water protection (Breivik and Jelle, 2012, p. 74). There are options available for roofs, facades, and windows (Jelle and Breivik, 2012, p. 74).

The manufacturers normally offer customized products (Jelle and Breivik, 2012, p. 74). There needs to be a certain amount of distance between the solar cells, which depends on the transparency level that is wanted and electricity production criteria, but the distance is usually 3-50 mm (Jelle and Breivik, 2012, p. 74). This space between the cells provides daylight, which means that this product has the benefit of giving lighting and produce electricity (Jelle and Breivik, 2012, p. 74).

There is several things that needs to be take into consideration when installing a BIPV system, one of them being making sure that there is an air gap underneath the solar cells in order to provide a flow of air that reduces the temperature of the solar cells (Jelle and Breivik, 2012, p. 69). If the temperature of the solar cells is too high, the efficiency decreases, in particularly with mono-and polycrystalline Si cells, so this air gap is very important (Jelle and Breivik, 2012, p. 69). The inclination angle and the geographical position towards the sun should also be heavily looked at when installing BIPV (Jelle and Breivik, 2012, p. 96). There also have to be accounted heat and moisture transport (Jelle and Breivik, 2012, p. 69).

There are cities around the world that have invested into BIPV, one of the places being Singapore, where a transition towards renewable energy is high on the political agenda (Lu et.al., 2018, p. 400). Singapore is also a city that is very urbanised and many skyscrapers that are very suitable for BIPV (Lu et.al., 2018, p. 400). When different parts of the world are starting to use this technology more and more, it can be necessary to review if this technology can beneficial in Norway somehow. With population growth and urbanisation, BIPV is a helpful solution to use the energy as efficient as possible. The costs of the BIPV system would include factors such as cost of components, design, and installation (Lu et.al., 2018, p. 400). The profitability of the BIPV system will be determined by these costs and the benefits they get through the actual energy generation (Lu et.al., 2018, p. 401). The loss of power through a BIPV system could be due to pollution particles in the atmosphere, shading, and bad orientation of the BIPV modules (Lu et.al., 2018, p. 401).

There are gaps of knowledge when it comes BIPV, and it hinders the promotion of the technology (Lu et.al., 401). The barriers of why BIPV has not taken off on the market, has not been studied as much up to this point. There are very few studies that have looked at possible barriers, but there are very little research done on the Norwegian market. There is also the fact that most of Norway's energy system consists of hydropower, which has led to less interest into other energy measures such as the PV industry (Hanson, 2018, p. 68). Norway is today one of the leading producers of hydropower (*nve.no)*. Norway has for many years used the water resources in Norway for industrial causes, and through research and innovation, NVE have been successful in using this resource for electricity purposes (*nve.no*). Hydropower has been at the forefront for NVE since they were established in 1921 (*nve.no*). Norway´s leadership and use of hydropower has led to the assumption that there is no need for new energy sectors, but

with the prices of solar energy going down, it could be interesting to look towards a different energy source for the future.

Research question

BIPV is still a fairly new technology so there is not massive amounts of research on this issue yet. The information from the academic side have mostly focused on the technology itself, such as how it works, the materials, and the longevity of the technology. What i would like to do is to study the BIPV technology in the Norwegian context. BIPV and the PV industry in general is still a relatively small sector in Norway, so it is interesting to study this further. I will use the theoretical framework of technical innovation systems (TIS) in this thesis. To give context to the emerging technology, I will pursue a case study with the case of Brynseng school in Oslo, which has been a pilot project for environmental buildings in Oslo (*futurebuilt.no*). To do this, I have come up with the following research questions:

1) How can BIPV become a competitive product on the market in Norway?
2) How can the case of the Brynseng school help the future of BIPV in Norway?

Chapter 2: Theoretical Framework

This chapter will present the theoretical framework. I have used the technological innovation systems (TIS) framework for the thesis. First, innovation systems will explained more broadly. Secondly, the framework is presented through the six functions by Bergek et.al. (2008). Some of the weaknesses and critiques of TIS will then be highlighted.

Schumpeter and Innovation

Joseph Schumpeter was the first person to emphasise the importance of innovation as part of economics and capitalism (Fagerberg, 2003, p. 125). He wanted to develop a theory of economic evolution, which is different than the theory of static equilibrium that many other economists developed (Fagerberg, 2003, p. 129). Schumpeter was very influenced by Karl Marx, and one element he borrowed was the idea that the evolution of the capitalist society was due to competition between firms (Fagerberg, 2003, p. 129). One way of competing was by to introduced new technology in order to increase the level of productivity (Fagerberg, 2003, p. 130). The firms that succeeded with this task, would improve their position on the market, and they firms that failed to introduce new and successful technology, were driven out of the market (Fagerberg, 2003, p. 130).

Schumpeter departs from Marx when he tries to explain the creation of innovations (Fagerberg, 2003, p. 131). He underlines that innovation is not the same as an invention, where the stress is on the fact that an innovation is "a specific social activity (function) carried out within the economic sphere and with a commercial purpose" (Fagerberg, 2003, p. 131). Inventions, however, can be carried out in many places and the commercialisation intent does not have to be present (Fagerberg, 2003, p. 131). When it comes to innovation, it could also involve using resources and equipment that already exist and create "new combinations", which Schumpeter would call the "entrepreneurial function" (Fagerberg, 2003, p. 131). This functions are pointed towards the idea of a systems perspective, where the aim is to study the functions and the pending results, and then locate it within a system (Fagerberg, 2003, p. 131).

Innovation systems

What is important to emphasise when it comes to innovation, regardless of the theoretical viewpoint, is that it is not a linear model (Fagerberg, 2005, p. 9). Rosenberg and Kline came

out with the idea that innovation happened in a particular way, however, this model is only relatable for some innovations (Fagerberg, 2005, p. 9). Innovation happens through several different stages, which most likely will be completely different from another innovation, and this is one of the many reasons for why innovation is an interesting field of study. What is so interesting with regards to innovation systems is that it places the innovation in a system with no regular or predefined patterns. This leaves an open space for discussion around the innovation.

Studying a concept in innovation can be a challenge, but in order to get a complete understanding of the different aspects of a chosen concept, a systems approach is a good choice for a framework. For this thesis, the interest is in understanding how a technological product (BIPV) can be competitive on the market. The factors that have an influence on this issue can be many, which is another reason for using a systems approach. When applying a systems approach, one needs to remember to distinguish the different approaches.

A core aspect to study innovation is to understand that most innovations do not come about alone or in isolation, but through a collaborative process with many different actors (Edquist, 2006, p. 183). They may collaborate with other firms, entities such as universities and research institutions, and it might be largely influenced by government bodies and the rules, laws, and norms that are created through them (Edquist, 2006, p. 183). Edquist also defined a system of innovation as "all important economic, social, political, organizational, and other factors that influence the development, diffusion, and use of innovations" (Edquist, 2001, p. 2). The systems approach consist of analysing the "determinants of innovations", not about the consequences of innovations, for example with regards to growth (Edquist, 2001, p. 2). Firms rarely innovate on their own, it is usually through learning and interaction between firms (Edquist, 2001, p. 3).

A commonly used type of system innovation is the national system innovation (NSI) framework, which was defined by Freeman as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, and diffuse new technologies" (Edquist, 2006, p. 184). There is also a sectoral and regional systems approaches. The sectoral systems of innovation focuses on specific groups or firms that create and produce products for a specific sector, whilst regional innovation systems refers to the diffusion of an innovation

within a geographical area (Edquist, 2006, p. 185). However, the thesis will not use either of this approaches, but rather a technological innovation system (TIS) approach.

Technological Innovation Systems

TIS, or technological innovation systems, is an analytical framework that has its focus on the technology. An innovation system is interested in looking at the processes that an innovation goes through and as a tool we use it help us understand dynamics among several components of a system (Bergek et.al., 2008, p. 408). TIS can be defined as "socio-technical systems focused on the development, diffusion and use of a particular technology (in terms of knowledge, product or both)" (Bergek et.al., 2008, p. 408). TIS helps out with the structural focus through a series of functions, which is a response to the critics of innovation systems and their weak structural components (Bergek et.al., 2008, p. 409). These functions of the system highlights what is achieved rather than what the dynamics are (Bergek et.al., 2008, p. 409). TIS has presented a number of steps that should be taken, not necessarily done in a linear order, and the person doing the analysis must be prepared for repetitions and changes of the process (Bergek et.al., 2008, p. 411).

Step 1 is the starting point and it is about deciding what the focus of the TIS should be, from breadth to depth, and product specific to a field of knowledge (Bergek et. al. 411). It is important to emphasise that this is not necessarily is very easy at first, and a common thing is to start from a broad angle and then focus on a specific topic as the analysist has gained more knowledge about chosen topic. After the topic has been defined, the actors in the TIS must be chosen as part of step 2 (Bergek et.la., 2008, p. 413). Since the chosen topic of this thesis is a relatively new technology it can be hard to identify which actors is the most relevant. The functions are underlined during the third step. These functions are the basis of the framework as they specify the areas that is necessary to cover in order to gain somewhat of an answer to the research question.

Function 1 emphasises the knowledge base and how broad or deep the knowledge of a particular topics is (Bergek et.al., 2008, p. 414). There are different types of knowledge, such as technological knowledge, market knowledge, scientific and so on (Bergek et.al., 2008, p. 414). Function 2 makes the researcher look at what drives this particular direction of research and what the incentives should be in order to get more people/firms/organisations to go for the

innovation (Bergek et.al., 2008, p. 415). In order to measure the function, it is put forward that one should look at their growth potential belief, the product prices and the incentives that derives from it. Then, one should look at the regulatory pressures surrounding the function, and one should look at the interest of the customers (Bergek et.al., 2008, p. 415).

Function 3 is called ´entrepreneurial experimentation´ about creating a map or overview over the different ´experiments´ that take place (Bergek et.al., 2008, p. 416). This map would consist of new entrants, which would also include the established firms that diversify into the field (Bergek et.al., 2008, p. 416). It would also consist of the varied types of applications, technologies used and other compatible technologies utilized (Bergek.et.al., 2008, p. 416).

Function 4 emphasises the market formation. The market formation can be divided into three different phases, where the earliest phase is a space where the technology can develop itself without much interference, and this can be called a "nursing market" (Bergek et.al., 2008, p. 416). The nursing market can go over into the "bridging market", where more actors get involved and the size of the TIS is extended, before it at last becomes a mature mass market (Bergek et.al., 2008, p. 416). To analyse the market formation aspect within TIS, one needs to identify the market phase, the users, the users´ purchasing process, the status of the demand profile, and whether the institutional structures facilitates market formation or if it needs institutional change (Bergek et.al., 2008, p. 416).

Function 5 is the ´legitimation´ function, which makes you look at how the society has accepted a new technology (Bergek et.al., 2008, p. 417). This is done by analysing how relevant actors view the legitimacy of the technology and by analysing the activities taking place within the TIS that can increase the legitimacy (Bergek et.al., 2008, p. 417). In order to analyse this properly, it is important to comprehend how strong the legitimacy factor is within the TIS (linkage between the TIS, legislation, and the value base), and who and/or what influences legitimacy (Bergek et.al., 2008, p. 417).

Function 6 is defined as ´resource mobilisation´, and it refers to the ability of the TIS to mobilise human capital, knowledge and competence, particularly in scientific and technological fields (Bergek et.al., 2008, p. 417). Other fields that may be necessary for mobilisation is within entrepreneurship, finance, and management (Bergek et.al., 2008, p. 417). To analyse the resource mobilisation, one can look at rising capital volume, increase in seed and venture

capital, increase in human resources, and by looking at other changes in its complementary assets (Bergek, et.al., 2008, p. 418).

Function 7, the final function,, is about the development of positive externalities. This would refer to positive processes such as economic processes, which are key to the formation and the growth of the TIS (Bergek et.al., 2008, p. 418). The central part that contributes to positive externalities is the entry of new firms into the TIS (Bergek et.al., 2008, p. 418). New firms can have influence on the market formation and the search direction, they can help facilitate proper legitimacy, and new entrants would increase participants in the system, which would result in development and diffusion of knowledge (Bergek et.al., 2008, p. 418). These are all the functions that the analysist must cover within the TIS framework.

TIS has become a very useful tool to analyse emerging industries, and the PV industry has been studied within a TIS framework (Hanson, 2018, p. 64). The reason for this chosen theoretical framework is because it situates a new technology or product in a system, where one can get a good overview of the actors potentially than can influence the future success of this technology. BIPV is a fairly new technology, with not many projects to look towards within Norway. That is why I want to focus on one case, which is the Brynseng school in Oslo, because it was the first nZEB (near-zero emission building) building with BIPV. By putting my focus on actors related to Brynseng and some other actors with BIPV knowledge, will hopefully give a good view and more information as to how BIPV can be a competitive product in Norway in the future.

Weaknesses and critiques

There is a need for the systems approach to become more "specific", which can be achieved through more empirical use of the framework (Edquist, 2001, p. 3). More empirical work could help the discipline aspect of the framework, and further develop and improve the theoretical framework (Edquist, p. 2001, p. 3).

The technology focus has been criticised for being short sighted and lacking focus on how the technology relates to broader contexts (Hanson, 2018, p. 65). For example, it has been argued that TIS might oversee or miss out on emerging or competing technologies (Markard et.al., 2015, p. 77). Another criticism is regarding the geographical aspect. It has been argued that by focusing on a TIS within a selected country, there is a possibility of missing out on global parts

of the TIS that can influence the outcome of the TIS (Markard et.al., 2015, p. 79). However, since there has not been much research on how TIS structures in different settings can influence the functions of the TIS, analysing TIS structures in different countries has been more and more welcomed (Markard et.al., 2015, p. 79).

Chapter 3: Methodology

This chapter will present the methodological approach for this project. The first section will go into qualitative research. Secondly, case study research will be explained as well the reasons for why this particular case is interesting and relevant. The third section will go through the data collection process, before it will explain the research ethics.

Qualitative research

When studying in the social science field, an important difference that comes up early is the difference between qualitative and quantitative study (Johannessen et.al., 2006, p. 27). These two methods have a different process and the look for different answers from their study. Quantitative studies are interested in counting phenomenons and mapping out prevalence, whilst qualitative studies says something about the quality or special features and characteristics of the phenomenon (Johannessen et.al., 2006, p. 27). Qualitative research is intended to understand and explain phenomenons from within in many different ways (Flick, 2007, p. 9). One way is by studying and analysing people individually or in groups. One can analyse interactions, whether it is through observation or through communication (Flick, 2007, p. 9). The other way to do qualitative research is through document analysis, such as texts, film, and images (Flick, 2007, p. 9).

The qualitative method is the most reasonable method for this project. The interest is in how BIPV can become a competitive project on the market, and since this is still very much a niche technology, the best way to gain knowledge about it is through qualitative study.

For qualitative researchers, there are usually two fundamental questions that they choose to tackle and they either have to do with social structures or with individual experiences (Hay, 2010, p. 5). How a person behaves is better explained by how they are positioned within a social structure or through individual experiences (Hay, 2010, p. 5). When it comes to the individual experiences, it is important to emphasise that they are individual. People experience the same events and places very different from one another (Hay, 2010, p. 7). It is also important to give a voice to subjects that may not often be heard, and these explanations are extremely valuable to a qualitative researcher (Hay, 2010, p. 7).

Within the qualitative research method, I have chosen to conduct a case study at the Brynseng school in Oslo. The school was a pilot project for BIPV in Norway and it is therefore a fitting case to study further within the TIS framework. In this section, I will go through the qualitative research method, the case study as research design, the data collection process, and, the ethical considerations.

The quality of research

When it comes to judging the quality of research, there has been developed four tests that can decide the quality of empirical research, case studies being one them (Yin, 1994, p. 32). The first test is to "construct validity" which looks to "establish correct operational measures for the concepts being studied´ (Yin, 1994, p. 33). It is important for the research to cover two steps in order to meet this test: 1) select specific changes that should be studied that relates to the objectives of the study, and 2) demonstrate that the selected measures of these changes actually reflect the selected changes (Yin, 1994, p. 34). The case study is on Brynseng school in Oslo, which is one of the first buildings in Norway with a BIPV system, which is why is it is a suitable case study for my project. By using one case study, aim is to study how a new technology can become competitive, with BIPV as the chosen technology. The data will be collected through interviews and documents available on the topic.

The second test is the "internal validity" test, which emphasises establishing a relationship, where also certain conditions lead to other conditions (Yin, 1994, p. 33). Internal validity is mainly in the focus of explanatory case studies, but if the researcher is wrong or incorrect and overlooks some causal factor that would have an effect on the result of the study, the research design have failed to deal with threats to internal validity (Yin, 1994, p. 35). Another issue with internal validity, is the fact that the researcher is interfering in a particular event (Yin, 1994, p. 35). When a case study cannot be directly observed, the researcher is interfering (Yin, 1994, p. 35). Examples of interference is interviews and documentaries, and the concern that arises is to be sure that the evidence is correct (Yin, 1994, p. 35). It is important that the researcher goes through all the possible outcomes and consider whether other explanations have been considered (Yin, 1994, p. 35). For my project, the research question is explanatory, which also means that this test essential. In order to do the research without bias and interference, I have analysed the data through comparisons (Flick, 2007, p. 102). The comparisons are done by highlighting which theoretical function are emphasised the most by the interviewee (Flick,

2007, p. 102). Then, I look at what the consistency and contradictions in the interviews (Flick, 2007, p. 102). By committing to these analytical tactics, this test will be responsibly done.

The third test is the "external validity" test which sets to establish a domain where the findings of the study can be generalised, meaning whether the findings are applicable to other areas (Yin, 1994, p. 35). There has been criticism towards single-case studies when it comes to external validity, in which they state that single cases are not sufficient enough for generalisation (Yin, 1994, p. 36). This can relate to my project, by asking whether the findings of how BIPV can become a competitive market product can be applied elsewhere? However, they are not focusing on the fact that case studies rely on analytical generalisations, where the researcher is wanting to generalise a specific set of results to a broader theory (Yin, 1994, p. 35). This means that the findings of one particular study could at a later stage be generalised (Yin, 1994 p. 36). For my project, I have chosen the theoretical framework TIS to answer the research question.

The fourth and final test of the quality of research is the "reliability" test. The reliability test is supposed to show that the study operations can be repeated and still lead to the same result (Yin, 1994 p. 33). It is important to emphasise that it means doing the same case again and again, not doing the same steps with a different case study (Yin, 1994 p. 36). The aim of the reliability test is to erase or minimize at best the biases and errors of a study (Yin, 1994, p. 36). The important part here is to document the procedure that the researcher has done, and in that way the next researcher can follow the exact steps (Yin, 1994, p. 36).

Case study research

Case study research "involves the study of a single instance or small number of instances of a phenomenon in order to explore in-depth nuances of the phenomenon and the contextual influences on and explanations of that phenomenon" (Hay, 2010, p. 81). The so-called "phenomenons" could be related to a process, an event, or a place (Hay, 2010, p. 82). Within academia, case study research is a good tool to explore, develop, and use existing concepts and theories (Hay, 2010, 82). Case study is best defined as an approach to research design (Hay, 2010, p. 82).

Case studies are a good research strategy to use because of the research question. The research question incorporates the word "how", which as well as the word "why" lead to explanatory questions (Yin, 1994, p. 6). Explanatory questions are more likely to use case studies as the

preferred research strategy, because these kinds of questions analyse links that happen over time, and is not limited to a particular incidence (Yin, 1994 p. 6). Case studies are a good research strategy when researching current and contemporary events, and it can involve different types of evidence, such as interviews, observations, documents, artefacts, and documents (Yin, 1994, p. 8).

There has been criticism of the case study as a research strategy. One criticism has been that the researcher has not been thorough enough when doing the project, which means they have either allowed for ambiguous evidence or the views have been biased throughout the research process (Yin, 1994, p. 9). There is also a concern that case studies are not sufficient enough to provide scientific generalisations (Yin, 1994, p. 10). Scientific facts are usually based on many experiments or studies that proves the same phenomenon under varied conditions (Yin, 1994, p. 10). What this means is that the case study does not represent a "sample", and the researcher´s motive is to expand theories more than frequencies (Yin, 1994, p. 10). Essentially, the case study is supposed to help with analytic generalisation and not statistical generalisations (Yin, 1994, p. 10).

For this project, the chosen case is a specific building. As the research question emphasises, the aim is to find out how BIPV can become competitive on the Norwegian market. However, there are not many cases where BIPV have been used in Norway, and the few buildings that have decided to pursue this technology, have been built in recent years. For this project, I chose to focus on one specific building and then find as many actors that was involved with this building. This project has a limited timeframe and therefore it would make a more wholesome assignment to narrow the scope to one building. I chose to focus on Brynseng school in Oslo. It belongs to Oslo Municipality and was a pilot project on the use of BIPV in Norway.

Brynseng school is also part of the Future Built project, where the aim is to build 50 buildings with the lowest greenhouse gas emission possible (*futurebuilt.no*). Future Built have projects in the Oslo region, meaning Oslo, Asker, Bærum, and Drammen (*futurebuilt*.no). The project associated with Future Built consist of kindergartens, schools, office buildings, cultural centres, urban areas, and cycling- and housing projects (*futurebuilt.no*). The projects require high architecture quality, must contribute to a good city environment, and be located near public transport opportunities (*futurebuilt.no*). All of these factors were part of my decision to choose

Brynseng school as the case study. In the next section, I will go into more depth on how I collected the relevant data.

Primary data: Interviews

The sampling methods for this project is a combination of semi-structured interviews face-to-face and via telephone, and computer-mediated communication (CMC). Interviews gives strength to a research project, because it gives access to information about events, opinions, and experiences (Hay, 2010, p. 102). Interviews are used to fill in gaps of knowledge, where other methods might not be able to (Hay, 2010, p. 102). It gives insight into other opinions and behaviours (Hay, 2010, p. 102). Interviews help to investigate behaviours and motivations that are complex, and it is a method where the interviewer can show respect over the interviewee´s viewpoint (Hay, 2010, p. 102).

With the rise of the internet and online communication, CMC has become an increasingly more used form of conducting research (Hay, 2010, p. 128). The most common form of CMC is e-mail communication (Hay, 2010, p. 128). It can involve sending a questionnaire or through several exchanges (Hay, 2010, p. 128). The communication I had was by emailing important questions from each theoretical function of TIS. Through experience, the informants answered more profoundly if there were less questions. Benefits of CMC can be getting in contact with people where distance might be an issue, and it can give the interviewer access to groups or individuals where social hurdles could hinder personal meetings (Hay, 2010, p. 129). The challenges with CMC can be loss of authenticity of the informants because you lose the face-to-face experience, and there are no room for follow up questions (Hay, 2010, p. 130). It also can leave out certain groups without access to technology (Hay, 2010, p. 131).

The process with these research project, started with a scoping process by contacting many informants and organisations that could potential have knowledge on the topic. The topic I was interested in was the solar energy in Norway and the issue of high release of green gas emissions from the building sector. This led me to ask questions about the BIPV technology. These contacts gave an overview over the solar sector in Norway and who can have any knowledge on BIPV, which helped with narrowing down who the interviewee´s should be. There is no data from the interviews in the scoping process that have been used in the thesis.

The actors chosen to be a part of the thesis was done through scoping, as mentioned, and

research into previous literature on the topic. From then on, the theoretical framework helped choose the actors to be interviewed. Since TIS requires the researcher to collect actors from different sectors and study their processes within a system, there are five actors from five sectors or industries that will be studied. The case study was on Brynseng school, which led me to interview the builder, the entrepreneur, the architect, and the financer, which is Enova. Another interview was conducted with the Norwegian Water and Energy Directorate (NVE) as the manager of the energy system in Norway (*nve.no*). The actors will in this thesis be referred to as the builder, the entrepreneur, the architect, Enova, and NVE. The interview with the entrepreneur happened through a personal meeting and over the telephone, which included a tour of Brynseng school. The interview with NVE and the builder took place face-to-face and was about an hour long. I used a recorder to conduct the interviews, except for the personal interview with the entrepreneur. The architect was interviewed through CMC, because time and scheduling hindered a personal meeting. Communication with Enova also happened via email because of scheduling and the fact that the headquarter is located in a different city.

The main ways of conducting interviews are through recording and taking notes (Hay, 2010, p. 119). For my project, both of these techniques were used depending on the interview setting. After getting in contact with the people I would like to interview for my project, the process started of deciding when to conduct the interviews and when. This project was conducted over the course of the summer break, which hindered the ability to meet some informants. I was able to conduct interviews with the builder, NVE, and a telephone interview with the entrepreneur before the summer break. The meeting with the entrepreneurial company took place after the summer break. The email exchanges with Enova and the architect happened both before and after the break. The interview questions were based on the six TIS functions laid out by Bergek et.al (2008). Each function had 1-6 questions that related to the topic and research question. The interview guide is attached at the end of the thesis.

When all the interviews was conducted, the analytical process began. First, I transcribed the interviews with the help of computer software program. After the transcription was done, I started to code the written interviews by categorizing along the TIS functions. This helped me get an overview over whether the informants referred to some functions more than others throughout the interview. Even though the interview was semi-structured and had questions from each TIS function, it was interesting to see whether other functions came up when discussing a different function. This could also help finding which function is the weakest and

which is the strongest. This would point to an area where there needs to be some improvements for the technology to become a competitive product. Other methods that was used was by comparing the interviews (Flick, 2010, p. 101). Were there some consistent and specific answers that came up in the different interviews? Then, I looked at what the differences were and creates an overview over what the findings were.

Secondary data: Document analysis

Another actor that is analysed to some extent in this project is the producer or manufacturer. Since there are no company in Norway that specialises in BIPV and the producer at Brynseng was an international producer, this has led to not being able to get a proper interview with this informant. Time and scheduling was also an issue with meeting a solar PV producer in Norway. For these reasons the best way of getting good source material for this was through secondary source materials, such as document analysis. This is not the same a s primary data, as secondary data is not produced with the objective to inform a research objective (Guest et.al., 2013, p. 223). However, secondary data can benefit within the interview data setting (Guest et.al., 2013, p. 223). Document analysis is a broad term and involves public records, historical archives, periodicals, personal narratives, corporate documents, or artefacts (Guest, et.al. 2013, p. 252). These types of additional data sources could help with the legitimacy of the thesis. When it comes to getting information about the production sector, some information has been gained through the other primary data informants and some information has been done through document analysis. The manufacturing and producer sector therefore not used as primary data, but it is additional information that can complement the TIS. There is also document analysis about solar PV and BIPV that will be used as additional resources.

Research and ethics

The ethics of research have been considered carefully throughout the research process. Ethics should be in considerations at all stages of the research process, from planning to sampling process (Flick, 2010, p. 70). It is important to inform the participants about their options and their rights throughout the research process (Flick, 2010, p. 72). I informed the participants that no personal details would be included, there would be anonymity throughout the research process, and I let them know that they could withdraw from the process at any stage. No personal details will be exposed in the thesis in order to protect individuals. I have chosen to refer to the informants as the occupation (the builder, the entrepreneur, the architect). Even though there are information about Brynseng school available to the public, for the sake of the

research process, the informants will be kept anonymous. Enova and NVE will be referred to as such, as there are no personal details that will be included in the thesis and these are large organisations that have information and data available to the public. Before the interviews were conducted, an application was sent to the Norwegian Centre for Research Data (NSD) to be able to conduct the interviews. The aim of NSD is to make sure the research is conducted under the principles of "open access, equal treatment, and sharing of research data" (*nsd.no*).

After the data had been collected, the recordings and the transcripts were saved codes that would not recognize the informants. When analysing the data, it is important to be fair and accurate with the collected information (Flick, 2010, p. 74). The data should not be kept for much longer than the researcher actually needs it for the research (Flick, 2010, p. 75). I let the participants know that the data would be deleted after the research is finished.

Chapter 4: Empirical data and analysis

This chapter will go into the empirical data that has been collected, and explain and illustrate what the different actors mean and contribute to BIPV. These actors have worked on the Brynseng school and others have knowledge and expertise on the BIPV industry and the market. First, the current status for BIPV in Norway will explained. Then, information about the case , Brynseng school, will be presented. After that, all the actors will be presented separately, where I will present what was discussed in the interviews.

Current status for BIPV in Norway

There was a report released in 2018 summing up the current status for BIPV in Norway. The original title is "Muligheter og utfordringer knyttet til bygningsintegrerte solceller (BIPV) i Norge 2018", which translates to ´Possibilities and challenges related to BIPV in Norway 2018´. FME Susoltech, BIPV Norway, The Norwegian Solar Energy Cluster, and the Norwegian Solar Energy Society were behind the report. The aim of the report is to explain what BIPV is and what the possibilities and challenges are with examples of existing and future projects. They also give some advice for what should happen in order for the solar energy sector to blossom.

The argument for why they choose to release the report now is because there is noticeable increase in interest for BIPV in Norway, it is a field that could be of interest for the Norwegian business sector, and it is important to push towards a sustainable building sector. This information can be found in the preface of the report.

As the thesis has already has explained, BIPV means that the PV-element has a building function as well as the task of producing electricity (FME Susoltech et.al., 2018, p. 4). It is estimated that the market for BIPV worldwide is roughly 5% of the global solar market (FME Susoltech et.al., 2018, p. 5). Multiconsult also estimates that the potential capacity for BIPV today is ca 26 terawatts (TWh) in existing private- and commercial buildings, and it will grow up to 32 TWh by 2030 (FME Susoltech et.al., 2018, p. 5). This shows that there is a lot of potential for BIPV to grow. Norway has so far (2018) installed 45 megawatts (MWh) of building-attached photovoltaics (BAPV) and BIPV, in which 18 MWh where installed in 2017. This shows huge increase and possible future business sector in Norway.

CASE: Brynseng School

Before I go further into what the different actors that has taken part in the assignment had to say, I will give some general information on the Brynseng school. The Brynseng school is a public school which is located in a part of Oslo called Østensjø, in the north-eastern part of Oslo (*futurebuilt.no*). The grades go from 1st to 7th, with enough space for 840 students and about 110 employees (*futurebuilt.no*).

It is the first nZEB in Oslo with a solar facade of 1046 m2. A big goal for the project was for it be a nZEB due to the importance of it being environmentally friendly. The nZEB target was helped by there being installed heat pumps and 20 energy wells, which have been drilled 250 meter into the ground on the school´s property (Nilsen, 2016, *tu.no*). There is a sports hall located on the top of the school with a translucent façade and good isolation (*futurebuilt.no*). The architectural decisions underline a futuristic perspective (*futurebuilt.no*).

Transport opportunities are very close by, making public transport a very viable option and could make people leave their cars at home. It is also located close enough to the school so that it is safe for both students and employees (*futurebuilt*). There are no parking lots by the school (*futurebuilt*). There are 250 bicycle racks (Nilsen, 2016, *tu*.no). Solar cells on the schools will cover 37 % of the facade, which will be 2845 m2 in total (Nilsen, 2016, *tu.no*). The solar panels also delivers about 105.000 kW (Nilsen, 2016, p. *tu.no*). The solar cells have been mounted on fire proof- and waterproof isolation, and the sports hall has a facade with a layered glass (*futurebuilt.no*). Within the glass, there are horizontal "straws" that will keep out heat and light during the summer, but still let in light and warmth during colder times (*futurebuilt.no*).

The Future Built criteria was that there had to be a 50 % reduction of released emissions during the process, which was considered throughout the areas of transportation, stationary energy, and materials used (*futurebuilt.no*). The elimination parking spots contributed to a big part of the reduction (*futurebuilt.no*).

The builder

The builder owns the building, and it is a public property. The Brynseng project is a total enterprise project, which means the builder appointed an entrepreneur, and the entrepreneur chooses producer and how to construct the project.

The first question that came up was the question about whether there has been an environmental focus for many years, in which the answer was that they have been certified with regards to the ISO-standard (International Standard Organisation) since January 2010. The ISO-standard is a tool that is supposed to provide a working model that requires continuous improvements with the environmental work (Oslo Municipality, 2003, p. 7).

They also mention that it helps with a "political leadership that have had a clear green agenda in the last few years". In 2012, it was decided that all buildings had to be passive houses, and since then there are about 30 passive houses in Oslo. In the last few years, there are more talks to build houses that are nZEB.

I asked about the profitability of Brynseng, which was a pilot project and they received 4.5 million NOK from Enova as support. The costs for the entire project was quite a lot, but this support helped with the figures quite a bit. However, even though BIPV replaces parts of the building materials, the total costs including planning and engineering still leaves the builder with very high costs. This means that even though the price of the solar panels are going down, the total costs of a project only goes down a little. Regardless, the price is going in the right direction and they see it as beneficial to invest in solar panels.

When I asked them whether they see a possibility of more BIPV on future projects, they explained that facades with solar cells are extremely beneficial for them, because of the fact that the school is not in use during the summer time. As long as the solar panels can be placed on the southern facade, as the southern facade provides more energy. Brynseng has a big facade with BIPV facing south.

I go on to ask about if there were any saving mechanisms that have been used or considered for the project. They explained that this year they just about surpassed the 100 kWt limit that comes with the "plusskundeordning" (meaning prosumers). The prosumers can transfer the surplus of energy to the power grid up to 100 kWt. If it exceeds this limit, the customer has to pay a yearly

fee to transfer power onto the power grid (Seglsten, *tu.no,* 2018). On weekends and sunny afternoons there could potentially be that the energy level goes beyond the 100 kWt limit, and since this builder is in charge of schools (large buildings lead to more energy production), the prosumer program is considered restrictive when it comes to the environmental ambition.

The builder decides the environmental ambition for the building at first. Most often their projects are total enterprises, where the entrepreneur has most of the responsibility, they said. When it comes to Brynseng, the builder´s description was that they wanted solar panels, the panels should be frameless, and that it would be integrated into the facade. It also had to be coloured black and the mounting and attachment should not show. These descriptions might have been too vague, they experienced. Since the technology is really new and the fellow project partners maybe not having that much experience in using it, the descriptions could have been a little more comprehensive. All in all, the use of BIPV was a learning experience for many of them.

When I asked about whether they have had any feedback from other actors on their experiences on the Brynseng project, their assumption is that the entrepreneur likes to be challenged with new tasks since they choose to take on these projects. This goes to the architects as well, even though the architects do not necessarily think about the energy production aspect in their process as much. Usually, the builder has to steer the direction a little bit in order for the environmental ambition to be properly integrated. At Brynseng, the problem was that there are some shadowing that needed to be taken into account, as well as a sports hall that was built on top of the building due to not enough space on the property. This gave some excitement and challenges to the design phase.

When it comes to the assumption that the building sector is fairly conservative, their overall impression is that the other actors involved in the building process are interested and likes to be challenged on new areas. I asked them about whether there is a lot of knowledge diffusion with regards to BIPV, in which the impression was that there was a lack of BIPV solutions. There was one supplier of solar and one supplier of facade materials, and they needed to collaborate to make it work. There is a much bigger market for solar cells and building-attached photovoltaics (BAPV).

The conversation goes on to talk about how BIPV is more beneficial than other PV solutions, which is mostly due to the fact that the building uses the energy itself and the majority is not wasted. Of all the energy produced at Brynseng, 85 % is used by the building, whilst 15 % must be transferred out on the power grid. If you choose to have solar cells on roofs, you might get in the situation that you have to sell a huge part of the energy production to a very low price. The profitability with BIPV is then very strong, and it is a product that will be used in the future. Solar PV will always be considered on new projects, they said. When asked about if there are any political factors that influence their decision to invest in BIPV or solar, the response was that the City Council has definitely emphasised the importance of environmental friendly buildings. This standpoint pushes them to invest and learn about the renewable products.

The entrepreneur

The entrepreneur was chosen by the builder as best suitable to take on this endeavour. The Brynseng project was a total enterprise project, meaning that the entrepreneur has a deal with the builder that they undertake responsibility for the construction. The interview with the entrepreneur happened via the telephone, which gave a good insight into their role in the BIPV and solar sector. I was also invited to a meeting at a later stage to discuss BIPV and the Brynseng project further. This contact was very viable for me in order to get a good view of the Brynseng school, since they as entrepreneurs were very involved. It was interesting to hear how they approached this project with the demands from the builder considering the BIPV technology for many people is unknown. I will now go into the content of the interview.

The interview started by going into the market opportunities of BIPV. The entrepreneur believes there are big opportunities for BIPV to become a competitive product and that there is a growing market. I further asked if they have any knowledge on what kinds of actors is mostly interested in solar energy, and their response was that it is for the most part public builders in the last few years. They are very committed to the use of solar panels at least. It does not mean that the private market is withholding on environmental friendly solutions, as the entrepreneur notice interest from their part as well. An example is Asko at Vestby, which has a huge solar panel.

Next, I asked if they see any possibilities of this technology becoming market competitive in the future, the answer is yes “because the price of solar panels are getting lower, and it will absolutely be competitive”. It is also emphasised how Norway will be even more connected to

the European market for electricity, and that there are fears of the electricity prices going up. The fear of higher electricity prices have been a huge debate with regards to the third energy package of the European Union, which also launched the Agency for the Cooperation of Energy Regulators (ACER). The fear among many Norwegians is that ACER will push the electricity prices much higher (Molnes, *tu.no,* 2018). The trade unions are worrying about cuts in jobs, because of the possible competition from foreign electricity companies (Molnes, *tu.no,* 2018). These reasons could lead to more interest in people wanting to produce their own electricity.

When I asked the entrepreneur about whether they thought more institutional changes were necessary, they point towards the fact that the surplus of the production of power that you want to export to the power grid, does not give much back to the owner/producer. The entrepreneur explains that being a prosumer is not beneficial enough for customers today, as it leaves huge amounts of wasted energy, and the politicians need to take this into account.

The entrepreneur said that there are more standards that they have to follow, when it comes to pressures from the climate change debate. When asked whether they had done many projects with BIPV in Norway, Brynseng is currently the only one with BIPV. However, they have done several projects with solar panels. I asked questions about the production of BIPV and if there are many Norwegian firms who specializes in BIPV. The answer here was that there are firms working with BIPV, but that the production of the actual panels will most likely continue to happen outside of Norway.

I further asked about their experience with BIPV, and they said that it was mostly a smooth process. However, there were some challenges with regards to the integration of materials and other building-related issues, but it was managed in a good way. When asked about the options of BIPV available to them, the response was that you have to look at it from project to project, because you will need to adjust it accordingly. The building industry will always come across some challenges, and those challenges could be different or change from each time. The knowledge about BIPV has mostly derived from the creative process at Brynseng, and through experiences and sharing of ideas. Since Brynseng is one of the first buildings in the country with BIPV, there was not that many places to get information about it, they said. I asked if there needs to be any particular information about the technology itself, and gave design as an example. The answer was that design, different types of panels, and installation processes and sorts will always be a field where knowledge is welcomed.

The interview goes on to talk about the collaborative process among the actors that worked on the Brynseng project. The entrepreneur explains how the builder decides the costs of the building and then the architect needs to adapt the materials in accordance with builder's wants. It is emphasised that the facade was very expensive, but they managed to make everything work out. BIPV has a positive reputation among different actors and sectors. The level of expertise when it comes to BIPV in Norway today is very high, the entrepreneur also said in the interview.

Towards the end of the interview, questions about the pressure from the public versus the private towards these kinds of buildings came up, and it was by far more pressure from the public. This was backed up by the demands for "passive houses" and "plus houses" and other certified standards. This lead to me asking about whether the Oslo City Council has been clearer and more demanding towards more environmental friendly housing and buildings due to the Green Party being elected into the council in 2015 (*oslo.mdg.no*). The answer here is that "Yes, as the public builder they will have more demands for environmental certificates". Finally, asked about if it is possible for start-up companies to become more involved in BIPV, or whether it is mostly diversifying firms who go into BIPV, in which the entrepreneur answered that it is probably more in the interest of the large firms or builders.

At the meeting with the entrepreneur at a later stage, I was able to get a better glimpse into the Brynseng project, and one of them being a tour of the school, both from the inside and outside. I was also explained more about the collaboration with the producer of the project. As mentioned, there was an international producer that was chosen, and one of the reasons for them being chosen was because of their ability to provide "all-inclusive" products. Another benefit that the producer provided to the project, was a type of suspension system, which Brynseng was one of the first to have. This suspension system was to help with the fact that the panel cannot be mounted onto wood, but steel. The fire department was also a part of the project.

Enova

Enova is a state-owned enterprise where the aim is to assist firms financially when choosing environmental friendly solutions (*enova.no*). Enova used to be under the Ministry of Oil and Energy, but in 2018 it was moved under the Ministry of Climate and Environment (Regjeringen.no, 2018). On the road to a society with low emission release, there needs to be assistance as the current solutions are very expensive and needs a push in order to actually get

through the process and innovate new technologies (*enova.no*). They also aim to get more environmentally friendly related technologies on the market (*enova.no*).

Enova will not provide help for projects that would happen without support from Enova and they do not support projects that have already begun (*enova*.no). This means that their support have to be a necessity in order to go through and finish the project (*enova*.no). Enova will only provide the financial support that is necessary, this is so that the resources will be spent in the best way possible (*enova.no*). They help out from the pilot phase and the all the way to the commercialisation phase (*enova*). There is also possibilities of supporting environmental friendly solutions at home through their subsidy program (*enova.no*).

I sent Enova an email where I highlighted the aim of my project: "my project is about how a new technology can be competitive on the market, and I am particularly interested in building-integrated photovoltaics (BIPV)". I further elaborated: "Enova supported the Brynseng school project and it would be interesting to hear what made you decide to support this particular project".

In the email, I put down three questions that I found to be important. 1) How do you think BIPV will develop in Norway? 2) Is there any possibility for it to become competitive on the market? 3) Will you support more use of BIPV? These questions were chosen because they directly ties up to the research question. Due to the fact that this was communicated via email, the way to get the most clear answers are through a small number of fairly specific questions. Enova´s headquarter is also located in Trondheim, which also makes interviews more difficult due to the distance.

Enova answered question 1 and 2 by replying: "when it comes to the future of BIPV in Norway, there is no doubt that this is a technology that is fast rising on the market´". They back this up my referring to the report on BIPV in Norway from 2018 by FME Susoltech et.al. To answer the third question, they refer to how they offer individual support for all types of solar panels through their support scheme called "El-produksjon" (El-production) for people who want to produce their own electricity. However, they also say that they do not specifically offer any support for either BIPV or BAPV. This is due to the technology now considered "mature enough" to not be a risk for future projects, and because of a "price development that has led to these products for the most part being economically sustainable without support". However,

there is support offered to “innovative projects, in which a completely new technology or concept are being used, through the support scheme “introduction of new technology in the building sector”. With all the answers, they offer more information by linking to their website. The important aspect here is how they emphasise how BIPV is “mature enough” for the market and how there has been a price reduction on BIPV products.

The architect

As what was mentioned in the methodology section, the architect has been contacted via email. That form of communication was the most appropriate way to get contact with this particular actor, and it still gave me knowledge about their part in the project and what their experience working with BIPV was like. The architect on Brynseng, when asked about whether they had any experience with BIPV beforehand, they answered “no”. After they used BIPV on Brynseng though, the architect that I was in contact with has used BIPV on every project since. They were further asked whether they though BIPV was challenging to work with, where the answer was “yes, it was new and we spent a long time looking for the right product”.

On the question of where they got their knowledge on BIPV from, their answer was that they contacted expertise domestically and internationally, which was also the answer they gave to the question of if there was a lot of information available for them about BIPV. When I asked the question “which actors are more interested in the use of BIPV?”, the response was that the builder is usually very interested and takes the societal responsibility very seriously. This was an interesting answer, because it was very different from what other actors have said in interviews. I even wrote down public and private as examples of actors, but the architect did not really touch on it. All they said was “I draw institutions of different types”, which could imply that they are approached from a variety of actors and/or sectors that seems interested in BIPV for their respective projects.

This particular architect firm have noticed increased demand for more BIPV on the market. They did not have any knowledge on whether there was any possibilities for BIPV to become competitive on the Norwegian market, but they referred to the suppliers for more information on this. Although, they did say that there should be more subsidy arrangements, both in the public market and private market.

When it comes to the profit aspect of BIPV, they do not see it as being profitable yet, but that there are more and more positive attitudes towards BIPV as a product. I asked them if they felt there was enough materials to on the market to work with, and there answer to this was that "it could obviously be more, but it gets better and better each day". They also highlight international firms being the main producers of BIPV and its related products. Their overall experience with BIPV was very positive and they go further to say "the school (Brynseng) is on its third year with many visitors taking huge interest in the technology, both from within Norway and outside of Norway".

In a presentation on the Brynseng school as part of the Future Built project, the architect talks about their experience with the project. They explain that their experience has been that "ambitious environmental goals, combined with a willingness to innovate and to search for a unique architectural expression, lead to exciting projects. This has provided those of us who planned the project with more knowledge, which we will be able to use in our endeavours" (*Brynseng Future Built,* 2017, p. 16). There seems to be overall positive attitudes towards using BIPV in future projects and it looks like it is a very interesting technology for many architects.

NVE

The Norwegian Water Resources and Energy Directorate (NVE) "manages the water resources, promotes efficient energy markets and cost-effective energy systems and contributes to efficient energy use" (*nve.no*). The directorate is a very central figure with regards to the national flood contingency planning and the national power supplies (*nve.no*). NVE operates under the Ministry of Petroleum and Energy (*nve.no*).

They emphasised that they do not have any specific analysis on BIPV, but they do believe it will be a big part of the future. I asked whether laws and regulations had anything to do with why BIPV have not become bigger at an earlier stage, and in response it was pointed to the support scheme by Enova. The support scheme has "given a little kick to the people who want to try it out themselves, but it does not give any extra focus on BIPV", it was said. "There are no other frameworks or regulations that hinder the prosumers, which has already been mentioned a little bit.

I asked about if there were any other schemes that relates to environmental friendly solutions, and I gave an example of "el-certificates", but their impression was that it is not many people

who have applied to the el-certificate scheme with regards to solar. This is because of lack of awareness about the program itself and people not knowing they can get this type of support. The other reason for not getting an el-certificate could be due to high administrative fees. Usually el-certificates go to wind parks or hydropower plants, and that fee is relatively small in relation to these big projects. To sum up, the support schemes for BIPV comes from Enova and being a prosumer.

I asked them about the future of the power and energy structure in Norway in relation to a more interconnected EU and EEA (European Economic Area), but this is very difficult to tell at this point. What we do know is that the EU wants more renewable energy. The other thing brought up here is that in the other European countries were they invest in solar energy, it is usually big solar parks. With these solar parks, there are state-run subsidy programs or auctions that are the basis for them being built. A reason for why this is not happening in Norway is because the power sector is de-carbonized, and it is therefore not considered necessary to give subsidies to the development of more power grids. Since the Paris Agreement, countries have committed to reduce their greenhouse gas emission, and they therefore need to have these auctions or subsidies. It is highlighted later, that there are no other programs that actually provides support other than Enova at this point.

Then, they emphasise that they "per definition is supposed to be technology neutral", which means that they would not develop a program specifically towards BIPV or solar. It would then be more directed towards power plants rather than a specific type of energy sector, but they are very positive to more solar power and solar technologies.

At one point during the interview, they remembered one thing that could help push the solar- and BIPV solutions ahead, which are the standards and classifications for housing, such as nZEB, plus- and passive houses. Stricter demands for houses and buildings could push into a more sustainable direction.

I asked NVE about if Norway as a member of the EEA has any influential power in the EU when it comes to the issue around solar, in which the response was that when many of the research projects and studies take place for environmental, technological, or economic reasons in relation to solar , Norway is not considered as part of them. This means that they try to influence in the sense that it provides Norway a spot in the research process by making the EU

use information from Norway and take it into account if it is available. Other than that, Norway is invited into meetings and can influence from there at an equal level with the other countries. There might be necessary to ally yourself with other countries in order to get through with your cause, but if you are able to argue that the cause will benefit Europe as well as the respective country, this should be a smooth process.

Next, I put forward the question about the Green Party entering the Oslo City Council and whether this has led to more focus on solar energy. They saw this as a possibility, since the Royal Castle and Bislett Stadium now have solar cells, that now political parties are emphasising climate change and sustainability more. An example they put forward was that one party said that the goal was to have solar panels on every public building. They do not know if i makes it more competitive, but it says something about how their willingness to pay for it has increased.

Then it was said that most people would probably say that the costs are the main hinder for BIPV, which they also confirm. There are not many projects one can use to measure the profitability, it really depends on how the price of electricity and the energy component of the power grid will evolve going forward. In a calculation, one can find a tiny text that explains that the assumption is that the price will increase or decrease with this much. If one assumes that the price will increase, and there can be many reasons for the price to increase, one of them being we are more connected to the outside world and an example being the quota market for carbon emissions, and that this pushes the prices up. With the assumption that prices will increase, the idea is that by producing the electricity ourselves, one will save money. The problem with this is that it is hard to tell whether the prices will increase and decrease for sure, so it can be hard to measure the profitability. When it comes to solar, one usually has to give a big pay-out at first and the profit will come later in the future.

The media can have an effect on how many people invest in solar, they think. Social effects can be a factor, for example if a neighbour invests in solar panels, one might be more inclined to invest oneself. They emphasise that they do not have a lot of knowledge on specific projects with BIPV. They come forward with another argument for BIPV, which they say could be that the energy sector is not involved with this. It is more up to the architects and other actors that work closely with the project. This argument came about after, I was asked about the maintenance the panels and the conversation went on to talk about how it is important for the

BIPV to enter at an early stage of the process. NVE mostly have to retrieve the knowledge about BIPV themselves, one of the ways being by following solar energy webpages on social media.

Findings

Most of participants could agree on the fact that BIPV can be a big part of the future and an important factor when it comes to new renewable solutions. The architect were the only one who hesitated, but they still emphasized how they have used BIPV continuously after the Brynseng project. The public sector is more interested in BIPV, due to the long pay off time. If the public sector invests into BIPV, it does not really matter when they get their money, as the money will be paid back eventually. Brynseng school being a pilot project, also invested into the best materials and it was supposed to have the best products from the beginning. A public school is also an investment for the future, and if it takes many years for it to be considered profitable, that is a good investment.

One argument that comes up, is also that due to the European energy market becoming more and more interconnected, there is a reason for wanting to produce their own energy. Fears of higher electricity prices as a factor for why people wants to do this. The debate surrounding ACER and the EU´s third energy package could have an effect as well.

It is also important to emphasise that the creation and diffusion of knowledge on BIPV is still going on. The Brynseng project was based on a trial and error basis, and learning through experience. BIPV is still an up-and-coming industry, especially in Norway, which means that there are lots of knowledge that is being shared among different actors and sectors. There is a lack of knowledge about the construction of BIPV, but this is also going through a learning phase. More knowledge on BIPV, would help and push for more innovative solutions when it comes to products, materials, and subsidy programs and financing.

At this moment, because investment into solar is expensive, subsidy arrangements have been important. Enova´s support definitely helped the project, but it is a type of support that will not be provided in the future since, BIPV is now considered a “mature” technology. Prosumers come up in a few of the interviews, and it is argued that the program is not suitable for large buildings such as schools. It is encouraged that politicians look at the prosumer program, and

it The cost up-front for a BIPV system is still very high, and add the long pay off time to this equation, the profitability is still not very big.

The participants acknowledged the influence of politics. Since the Green Party was elected into the City Council, the aim towards greener buildings was set in stone. Along with increased pressure from the general public and the international organisations to take climate change seriously, there has definetly been an increase in willingness among leaders and politicians to emphasise the environment in politics. The ISO-certification, BREEAM, and environmental ambitions for housing also helped with that focus.

The TIS function that is the weakest would be the "market formation". Despite increase interest into solar and BIPV, the market is still small and there are not many manufacturers available. By making this function stronger, BIPV can gain a bigger momentum. I would say the "entrepreneurial function" is very important for this to happen, because it facilitates more and better quality products available. The strongest function is "influence on the direction of research". There is an external pressure towards sectors to transition and political implications such as green parties gaining momentum in politics. Even though it is small, the interest into solar and BIPV is increasing. There also needs to be more focus on subsidies and incentives for more BIPV investments.

Additional data.

There are very few producers of BIPV in Norway. The producer at Brynseng is an international producer and was chosen by the entrepreneur due to them being able to offer an all-inclusive product, as mentioned in the entrepreneur section. There are no producers in Norway that produces or specialises on BIPV materials.

The issue with the PV industry is that there are many different steps when it comes to the production and manufacturing of PV modules. To be able to convert light to electricity, the requirement is that you need high purity materials (Normann and Hanson, 2015, p. 16). The dominant material is silicon, which is then melted into large blocks of crystal and then sawn into thin wafers, which then goes through a chemical procedure in a cell process and then constructed on the modules (Normann and Hanson, 2015, p. 16). The supply chain for PV modules consist of raw-material production, wafers and ingots, system (firms that install PV systems), machinery and equipment, finance, and consultancy/R&D (Normann and Hanson,

2015, p. 16). Most of the firms that work with PV modules can be categorized into raw materials (mostly silicon), system, and consultancy and R&D (Normann and Hanson, 2015, p. 16). There is only one firm that produces wafers and ingots, and there are no firms that produce modules in Norway (Normann and Hanson, 2015, p. 16).

There can be drawn some similarities between other related industries. There has been done some studies on the offshore wind industry (OWP) and the PV industry. For many producers in both the OWP- and PV industry, the most critical factor for them to succeed is the price criteria, and the product quality as the second most important criteria (Normann and Hanson, 2015, p. 27). This also proves that incremental innovation is very important, because it leads to improvements in the technology that can have positive effects on its competitive advantage: "Increasing product efficiency and competitive advantage may often be achieved through continuous improvements in quality or reduction in costs, rather than as result of major research breakthroughs" (Normann and Hanson, 2015, p. 27). The PV industry can also find it demanding to find customers (Normann and Hanson, 2015, p. 29), but with the pressure from politicians and the public, this might be changing. Research and development (R&D) with regards to BIPV, can have a positive effect on BIPV. The quality of the technology is very important for it to succeed.

Another factor is that there is a lack of emphasis on domestic market opportunities, which can provide barriers for other functions in the TIS, such as the entrepreneurial function (Normann and Hanson, 2018, p. 498). This means that a strong marked in related industries could lead to more interest into this technology, by introducing customers to the new industry (Normann and Hanson, 2018, p. 498). A lack of a home market for BIPV could also mean that it can meet challenges when firms are trying to internationalise (Normann and Hanson, 2018, p. 497). The example of OWP in Norway is that they have found it less problematic than first imagined when transitioning from oil and gas to OWP (Normann and Hanson, 2018, p. 499). The group of suppliers were mostly from the maritime industry, so transition from one industry to another was not as big of a problem (Normann and Hanson, 2018, p. 499). It is less problematic for related industries to adapt to another industry (Normann and Hanson, 2018, p. 499).

Since Norway, has such a strong oil and gas industry and with an increasingly large OWP industry, there are possibilities that the PV industry can take off as well. Even though the market for solar is not very big in Norway, the interest in renewable energies are very much present.

This could lead to more focus on solar for many firms, and then BIPV interest will follow. Taking advantage of a related market formation would still have some obstacles, such as different industries having local market attributions, which can be a challenge to transfer to related markets (Normann and Hanson, 2018, p. 498-499).

Even though there are possibilities for related industries to influence the TIS of BIPV, there is still nothing that says that solar energy will take over from oil and gas at this moment. However, there are advantages in having a large energy sector that can diversify into other related sectors. These firms, though the activity is not their main activity, have built this exploration on their experiences in the core industry (Normann and Hanson, 2015, p. 20).

Weak market formations in a TIS can affect other functional patterns negatively (Normann and Hanson, 2018, p. 499). However, BIPV is still being considered a new technology and the market formation for BIPV in the TIS is still weak. Most interest from firms into BIPV are from the building sector and not from other energy sectors. On the issue of policy, there are opportunities for allowing smaller firms that want to explore the BIPV industry access to research resources, finance, and international markets (Normann and Hanson, 2018, p. 500). However, with the European energy package, this type of policy measures might not be that popular in the rest of Europe (Normann and Hanson, 2018, p. 500). These types local suppliers and manufacturers would probably have issues being approved by the free trade rules in the EU (Normann and Hanson, 2018, p. 500).

Chapter 5: Discussion and conclusion

This section will sum up the answers to the research question, before there will be some concluding remarks.

The first research question was:

1) *How can BIPV become a competitive product on the market in Norway?*

There are many factors that can contribute to BIPV becoming a competitive product on the market. The first issue that needs to addressed are the subsidy- and incentive solutions. As of right now, the only financial help is through Enova and as prosumers. The problem with the Enova support, is that it is only used for innovative solutions that are not on the market yet. Brynseng got Enova support, due to the innovation aspect BIPV. Now BIPV is not considered as new and innovative yet by Enova. This does not mean that the product is market competitive, but it emphasises that is has entered the market sphere. Even though the market is small for solar PV and BIPV, there is increased interest in the technology, which will promote more research on BIPV. This could also lead to more firms diversifying into BIPV production.

The participants also emphasised the prosumer program as not sufficient enough for today´s uses of solar energy. The politicians should consider this program more carefully, and provide a new version where there is more to gain from exporting the surplus power out on the grid.

The climate change issue as one of the most defining issues of our time and with the pressure from the general public to adapt to a more sustainable society, could also be a factor to take in. The fact that Norway already has a big oil and gas sector, can be influential for firms to look towards the solar and BIPV industry.

The important thing to remember, is that the price of BIPV systems as they are today are way too expensive, and there needs to be incentives to change the energy use. The fact that Norway already has hydropower as main source of electricity, can slow down the process of BIPV becoming competitive on the market. However, it is important not to focus too much on this, but instead increase the research and knowledge on BIPV materials, products, and conditions

The second research question was:
2) How can the case of the Brynseng school help the future of BIPV in Norway?

The Brynseng School can help more interest into BIPV systems because it was built as a pilot project. Being one of the first nZEB in Norway can also influence other projects. The participants in this project emphasised that they have worked on more BIPV projects since working on Brynseng, and that these solutions are always under consideration during the planning and design phase.

This school was built using the best quality products, which meant that the total cost was quite expensive. There were some reduction in the fact that the façade materials were replacing traditional building materials. For Brynseng this was an investment for the future. It will have huge environmental benefits and a school is built to last over many years. This will also give time for the builder to make profit. The participants provided interesting views and solutions to BIPV, and it has been interesting to listen to how they have tackled the BIPV, especially since there are not many previous projects to learn from.

Relation to TIS

Through studying the BIPV technology within a TIS framework, it has enabled me to get an informative overview of the system in which BIPV is located. The chosen participants in the project came from different occupations in the building and constructing, and it was really beneficial to hear from them. Interviews with other organisations such as Enova and NVE, was essential in gaining knowledge about some of the forces that are critical to the success of BIPV.

The "market formation" function is considered to be the weakest function, and by making this function stronger, BIPV could be on the way of becoming a competitive product on the market. The "influence on the direction of research" is considered to be the strong function due to strong external pressure to reduce the greenhouse gas emissions in the atmosphere.

Future research

There is still much research to be done on BIPV. It is still considered a new technology, and knowledge on a variety of areas relating to BIPV would be beneficial. In this thesis, I chose to study BIPV within a TIS framework, but there would be a lot of necessary knowledge that could

come from other theoretical frameworks. I would suggest studying BIPV from a strategic niche management view. This framework provide a view from the niche perspective. BIPV, being relatively small on the market still, can be considered a niche. There is a lot of interesting research that could come from this perspective.

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INTERVIEW GUIDE – Technological Innovation Systems (TIS) functional pattern.

1. "Knowledge development and diffusion"
    a. Where does most of the knowledge around BIPV come from?
    b. How has the knowledge development occurred? (upstream process, downstream process).
    c. What kind of knowledge is available (scientific, technological, production, market, logistics, design)?
    d. What kind of knowledge is lacking?

2. "Influence on the direction of research"
    a. Has there been any external pressures that has affected the direction of research?
        i. Local pressure?
    b. How has the climate change debate affected the direction of research?
    c. What sources are necessary for further development?
        i. Policy and regulations
        ii. Incentives, subsidies
    d. How is the demand from the customers?

3. "Entrepreneurial experimentation"
    a. Who are and have been investing in this technology?
    b. Are there many firms specializing in this field?
        i. How many are new entrants?
        ii. How many are diversifying firms?
    c. How many different products/solutions are available?
    d. What type of technology/product is more widely used?
        i. Why is it more used than others?
    e. How were your experiences working with BIPV?
        i. What is different about it?
        ii. Positive and/or negative experiences?

4. "Market formation"
    a. How big is the current market share?
        i. Is it a profitable market?
    b. Is there an opportunity for this technology to be competitive on the market in the future?
    c. Is the demand increasing/decreasing?
    d. Who are more interested in this technology?

e. How does different sectors relate to this technology?
f. Is institutional change necessary?

5. “Legitimation”
    a. How strong is the legitimacy of the technology?
        i. Is it emphasised in legislation?
        ii. Has it influenced industry/firms/institutions´ behaviour?
    b. Has this legitimacy influenced the demand?

6. “Resource mobilization”
    a. Are there more investment in the technology?
        i. Seed and venture capital?

Structure based on:
Bergek et.al. (2008) ´Analyzing the functional dynamics of technological innovation systems: A scheme of analysis´, *Research Policy,* Elsevier, pp. 407-429.